United States Environmental Protection Agency | Office of Research and Development

National Exposure Research Laboratory
Research Abstract
Government Performance Results Act Goal: Clean Water

Significant Research Findings:

Selection of Candidate Eutrophication Models for Total Maximum Daily Loads Analyses in Support of the Clean Water Act

Scientific Problem and Policy Issues

The effective assessment of water body impairment by nutrients requires modeling tools that can consider a broad range of variables and processes. In many situations, nutrient fate cannot be represented without consideration of various biotic variables and nutrient-biota processes.

Section 303(d) of the Clean Water Act requires the development of Total Maximum Daily Loads (TMDLs). A TMDL is an estimate of the maximum pollutant loading from point and nonpoint sources that receiving waters can accept without exceeding water quality standards. Models are needed to characterize sources of nutrients and sediments and their relative loadings. Models are also needed for streams, rivers, lakes, and estuaries to predict how loadings of nutrients and sediments may result in adverse impacts such as excessive algal blooms, low dissolved oxygen, and related fish kills.

The National Exposure Research Laboratory has undertaken a study to evaluate models for use in identifying TMDLs.

Research Approach

The study objective was to identify and evaluate full-capability, water quality-based receiving water models. Two high priority research needs were identified, from which three lists were developed.

1. A list of processes/variables needed for TMDL assessments that are focused on eutrophication problems (eutrophication is the process by which increases in mineral and organic nutrients reduce the dissolved oxygen in a body of water, creating an environment that is more favorable to plant life, such as algae, than to animal life),
2. A list of additional criteria for evaluating the potential usefulness of the candidate models as tools for developing TMDLs related to end points indicative of eutrophication, and

3. A preliminary list of models useful for developing TMDLs related to end points indicative of eutrophication.

From these lists, a four-step procedure was used to evaluate the candidate models.

1. Produce a study methodology.

2. Present the results of the detailed model science, usage, and application evaluation in the form of comparison matrices and explanatory text.

3. Document the comparison results of the eutrophication capabilities of the receiving water quality models that provide a means to evaluate nutrient (i.e, nitrogen, phosphorus, carbon) cycling by considering water-quality based variables and processes.

4. Evaluate the potential of the selected receiving water quality models for linkage with an overland flow model such as the Hydrologic Simulation Program - FORTRAN (HSPF) to provide a more versatile and comprehensive modeling system.

The model evaluation was comprised of three elements: hydrodynamics, sediment, and nutrient cycling. Candidate models were compared head-to-head using general criteria. Afterwards, more subtle differences between similar models (e.g., 3-D models) were identified using detailed analysis.

Three aspects of model support were evaluated: model application aids, user support, and model usage. An additional area of model comparison focused on model code and architecture issues that might affect the ability to initially link the water quality models to watershed models. A static analyzer was used to analyze the FORTRAN codes.

Results and Implications

In total, over 60 models were eliminated from further consideration because they failed to meet one or more of the evaluation criteria. Of these, over 50 models were eliminated either because they did not represent adequate water quality variables and processes or because they did not include dynamic hydraulics. A handful failed the criterion related to availability of code. A few reservoir or estuary models failed the criterion that they must be multi-dimensional.

Based on this detailed screening, seven models satisfied the minimum requirements imposed by the screening criteria. These seven models, and the type of water body they can most appropriately be applied to, are the following:

HSPF-RCHRES: high-variability rivers and streams

CE-QUAL-RIV1: high-variability rivers and streams

WASP/DYNHYD5: high-variability rivers and streams, and one-dimensional tidal estuaries

CE-QUAL-W2: narrow, stratified estuaries, lakes and coastal regions, and high-variability rivers and streams

CH3D-WES: geometrically and dynamically complex water bodies

GLLVHT: geometrically and dynamically complex water bodies, and vertically mixed, shallow estuaries, lakes, and coastal regions

EFDC: geometrically and dynamically complex water bodies, and vertically mixed, shallow estuaries, lakes, and coastal regions

There is sufficient evidence to suggest that the science in the water quality based models should start to migrate towards ecological end points. With the close cooperation of the original model developers, each code should be upgraded to reflect these processes. The relative effort for each code is proportional to the size of the code. Model upgrades that are done in conjunction with a migration towards FORTRAN90/95 features (such as dynamic allocation of memory and a more modular design) would be useful to allow more sharing of code and use of standard utilities, although these benefits will be somewhat offset by slightly less efficient code.

Research Collaboration and Publications

The simulation strategy was designed and conducted by a research team at the National Exposure Research Laboratory's Ecosystems Research Division, which included Robert F. Carousel and support from the Office of Water contract 68-C6-0009. The work was presented at several TMDL workshops including workshops in Chicago and San Diego. A five-series journal article was developed based on this research and was submitted to the *Journal of*

Environmental Engineering for peer review and publication.

Imhoff, J.C. and Carousel, R.F. "Selection of Candidate Eutrophication Models for Total Maximum Daily Loads Analyses in Support of the Clean Water Act: a) Study Methodology." *J. Environmental Engineering* (submitted).

Imhoff, J.C., Carousel, R.F., and Yager, R. "Selection of Candidate Eutrophication Models for Total Maximum Daily Loads Analyses in Support of the Clean Water Act: b) Model Comparison." *J. Environmental Engineering* (submitted).

Imhoff, J.C., Carousel, R.F., and Yager, R. "Selection of Candidate Eutrophication Models for Total Maximum Daily Loads Analyses in Support of the Clean Water Act: c) Nutrient Enrichment Processes Comparison." *J. Environmental Engineering* (submitted).

Imhoff, J.C., Carousel, R.F., Kittle, J.L., Jr., and Duda, P.B. "Selection of Candidate Eutrophication Models for Total Maximum Daily Loads Analyses in Support of the Clean Water Act: d) FORTRAN Code Comparison." *J. Environmental Engineering* (submitted).

Imhoff, J.C., Carousel, R.F., Allison, J., and Yager, R. "Selection of Candidate Eutrophication Models for Total Maximum Daily Loads Analyses in Support of the Clean Water Act: e) Nutrient Enrichment Processes Enhancements from an Ecological Perspective." *J. Environmental Engineering* (submitted).

Future Research

The U.S. EPA's Office of Research and Development will be supporting the EFDC model through the Center for Exposure Assessment Modeling http://www.epa.gov/ceampubl/ at the Athens Ecosystems Research Division.

Contacts for Additional Information

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